9162
new 82-10

ontario hydro
research division

COMPLIMENTARY COPY
Please Credit Ontario Hydro Research if Reproduced in Whole or in Part

To: Mr. J.V. Doyle
Manager
Civil Works Department
Thermal and Hydraulic Generation Division

Attn: Mr. G.F. Smith

PINE PORTAGE GS
NEW GEOTECHNICAL INSTRUMENTATION

C.B.H. Cragg

This report documents the new instrumentation installations made at Pine Portage GS by Civil Research in 1987. Descriptions of new normal and inverse pendulums, alignment survey stations, benchmarks, crack meters and weirs are included. Initial readings are provided for most of these instruments.

1.0 INTRODUCTION

A review of instrumentation at Pine Portage/1/ recommended rehabilitation of existing observation wells and uplift cells and installation of many new instrumentation devices. This instrumentation is required to monitor deformation, uplift and leakage and thus provide data for performance review of the structure. This report documents the repairs and new installations of instruments performed by Civil Research. Records of initial readings are also provided. Installations and repairs carried out by the Geotechnical and Hydraulic Engineering Department are documented elsewhere.

2.0 SITE DESCRIPTION

Pine Portage GS is a major concrete gravity dam located on the Nipigon River (Figure 1). This concrete dam has a maximum height of 140 feet and a crest length of 3106 feet. Construction of this project was completed in 1950.

3.0 INSTRUMENTS INSTALLED OR REPAIRED

The purpose of the new instrumentation is to provide information on structural deformations in both the horizontal and vertical directions and on leakage through the structure. Uplift cells were repaired to improve knowledge of uplift pressures for use in design reviews. Details of these installations and repairs are presented in the following sections.

DSP#410.1-48.036--1

job	file	date	report no.
44-136-575	843.2	February 4, 1988	87-328-K

89-02609/

LEGAL NOTICE

This report was prepared by Ontario Hydro and, while effort has been made to assure the accuracy and applicability of the material contained herein, neither Ontario Hydro nor any person acting on its behalf:

(a) makes any warranty, express or implied with respect to the use of any information, apparatus, method or process disclosed in this report or that such use may not infringe privately owned rights; or

(b) assumes any liabilities with respect to the use of, or for damages resulting from the use of, any information, apparatus, method or process disclosed in this report.

The instrumentation that was installed or repaired by Civil Research includes the following items:

(a) 1 inverse pendulum in the inspection tunnel at chainage 19+70.

(b) 1 normal pendulum from crest level to inspection tunnel level at chainage 19+73.5.

(c) 20 brass survey caps for alignment survey of the dam crest.

(d) 2 benchmarks, consisting of brass caps, at each end of the dam.

(e) ten flow monitoring weirs in the gutters of the inspection tunnels.

(f) eight crack meters on the dam crest.

(g) repair of 12 uplift pressure cells at chainages 19+21 and 28+08.

4.0 MAIN DAM INSTRUMENTATION DETAILS

Construction details and initial readings for the instruments listed above are presented in the following sections:

4.1 Inverse Pendulum

An inverse pendulum was installed in the inspection tunnel at chainage 19+70 which is near the access tunnel from the powerhouse. The pendulum hole was drilled NQ size from the floor of the inspection tunnel (elevation 780.0 ft) to a depth of 65.3 feet. Drilling procedures developed by Hydro Quebec/2/ were used to keep the hole plumb in this installation. Figure 2 shows the location and amount of correction required in drilling this pendulum hole. After coring 31 feet of concrete, this hole passed through the box drain and into the bedrock. Coring was halted at 65.3 feet, some 15 feet short of the proposed depth, when several attempts to correct hole alignment were not successful. (This was the second drill hole in this location, the first was abandoned at a depth of 19 feet due to alignment problems.) Core from this hole will be logged by staff of the Geotechnical and Hydraulic Engineering Department at a later date.

A set of datum readings including microlevels on the reading table and autocentering readings/3/ were performed on this inverse pendulum (Figure 3). The datum readings will provide a reference for monitoring deformation of the dam relative to its foundation. The microlevel readings will show if the reading table has been disturbed. Autocentering readings may be used to locate the source of any significant movement occurring within the length of

the inverse pendulum. Datum readings on the inverse pendulum are shown on Table I. The autocentering device readings are contained in Appendix A.

4.2 Normal Pendulum

A normal pendulum was installed at chainage 19+73.5 of Block 55 of Pine Portage GS - the same block as the inverse pendulum. Using the same drilling procedures as in the inverse pendulum hole, this hole was drilled from dam crest level (elevation 860.0 feet) through 72 feet 2 inches of concrete to intersect the inspection tunnel. Figure 4 shows the location and amount of correction performed in drilling the normal pendulum hole. Large deviations at the top of the hole were caused by three steel conduits in the drill path. Datum readings on the normal pendulum and reference microlevel readings are shown on Table I.

4.3 Survey Monuments

Twenty survey stations and two reference monuments were installed on the crest of the dam at the chainages listed in Table II and shown on Figure 5. All stations and monuments were installed on line for use in alignment surveys. The survey stations consist of brass caps, 2.5 inches in diameter engraved "CIVIL WORKS 1987", grouted in the surface concrete of the dam.

The west monument, at chainage 2+80, consists of a 12 inch diameter concrete pier anchored by reinforcing bars to the concrete cutoff wall which is 3.5 feet below the surface of the earth dyke at this location (Figure 6). The east monument, at chainage 31 + 06, consists of a 4 foot square concrete pad attached to the left abutment rock outcrop just above the crest level of the dam (Figure 7). A brass cap, similar to that used for the survey stations, marks the reference point on these two monuments (Figure 8).

Appendix B contains initial level and alignment survey measurements on these monuments performed by Civil Works personnel.

4.4 Weirs

To monitor leakage captured by the drainage system within the dam, ten weirs were installed in the inspection tunnel gutters. These weirs are generally located in pairs, one on each side of each collector sump which conveys leakage to the tailrace (Figure 9). Of these ten weirs, seven are of the V-notch type and three are of the broad crested type. Table III shows the dimensions, type and chainage of these weirs in the west, east and powerhouse inspection tunnels. Weir readings are recorded on a standard form (Table IV).

4.5 Crack Meters

Eight sets of crack meters were attached to the deck of the dam at the sluiceway piers. As shown in Figure 10, each crack meter set consists of two pairs of aluminum angle irons, anchored to the surface concrete on either side

of a prominent crack using 6 inch bolts. Pairs of angle irons are used to measure the crack displacement in two perpendicular directions at each location. Measurements are made with a digital depth micrometer similar to that used for the pendulum monitoring. Thermocouples embedded up to 18 inches below the concrete surface are monitored at the same time as crack measurements are taken (Figure 10). Initial readings on the crack meters are shown on Table V.

4.6 Uplift Cells

Twelve uplift cells, six at chainage 19+21 and six at chainage 28+08 were installed during construction. These cells were rehabilitated with individual valves and gauges as shown in Figure 11, as requested/1/.

5.0 SUMMARY

New instrumentation consisting of an inverse pendulum, a normal pendulum, survey stations, reference monuments, weirs and crack meters was installed at Pine Portage GS. Existing uplift cells were renovated. Locations, installation details and initial readings were documented in this report.

ACKNOWLEDGMENTS

The successful completion of this project is due primarily to the hard work of Mr. A.G. Morton, who prepared all the instrumentation and performed the field installation. Credit is also due to staff of the Geotechnical and Hydraulic Engineering Department and the Civil Works Department for the assistance and support given to Mr. Morton in the field.

Approved by:

T.W. Klym
Manager
Civil Research Department

Prepared by:

C.B.H. Cragg
Senior Engineer
Soil Sciences Section

Reviewed by:

T.J. Carmichael
Supervising Engineer
Soil Sciences Section

AGV/CBHC:LM

REFERENCES

1. Bennett, A.R. "Pine Portage GS - 1987 New Instrumentation Proposal". Civil Works Department Report, August 1987.

2. Dubreuil, L. and R. Hamelin. "Vertical Drilling of Inverse Pendulum Holes". Second Canadian Symposium on Mining, Surveying and Rock Deformation Measurements, Kingston, Ontario, 1974.

3. Hamelin, R. and B. Boyer. "Instruments for Monitoring the Profile of Vertical and Inclined Holes". 35th Canadian Geotechnical Conference, Montreal, 1982.

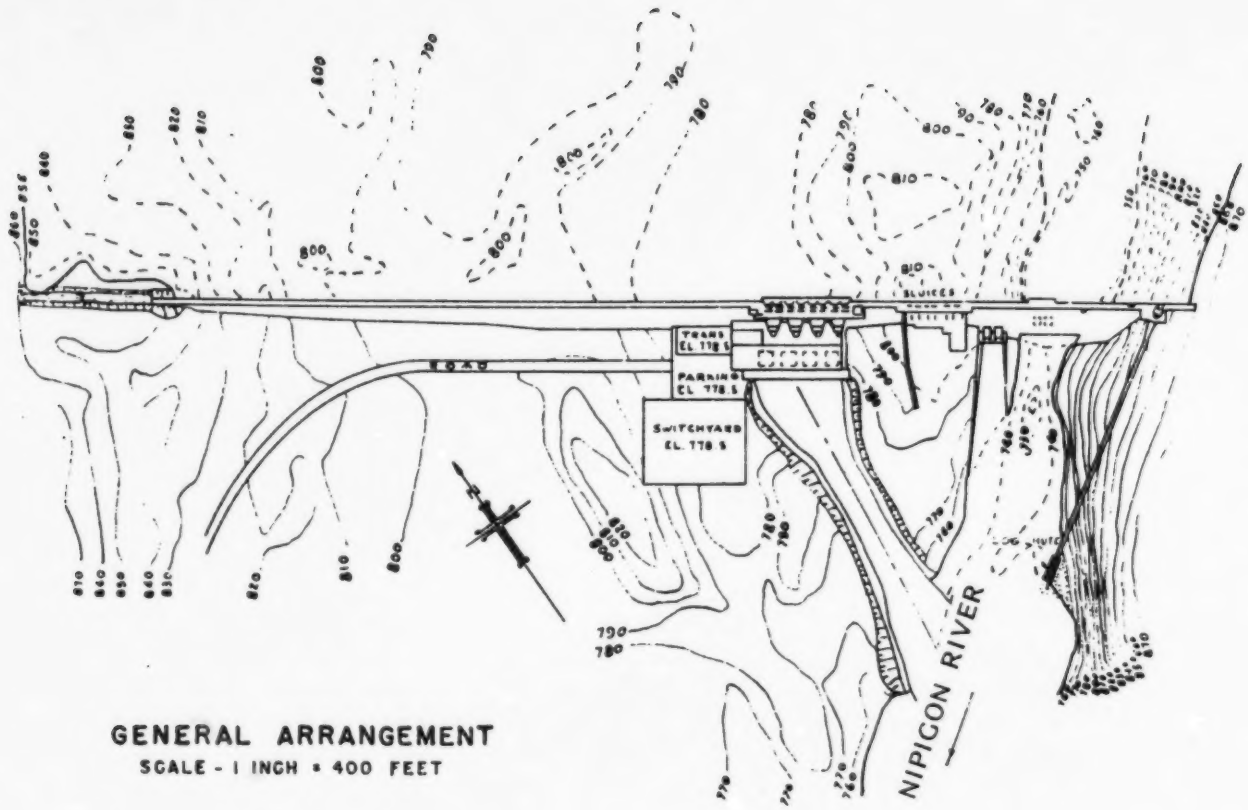


FIGURE 1

PLAN OF PINE PORTAGE GS
(From Drawing 254-E-70)

176325-RD

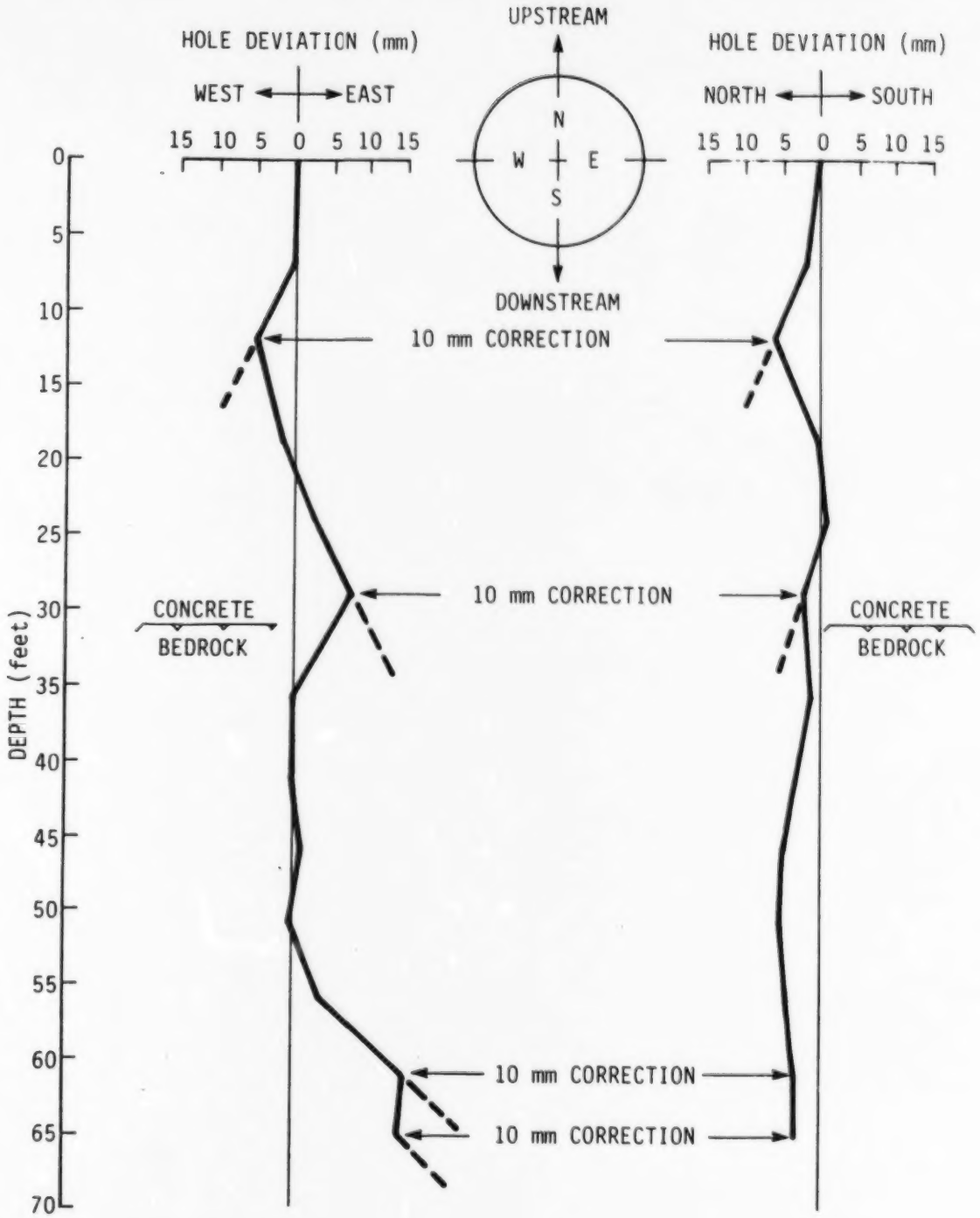
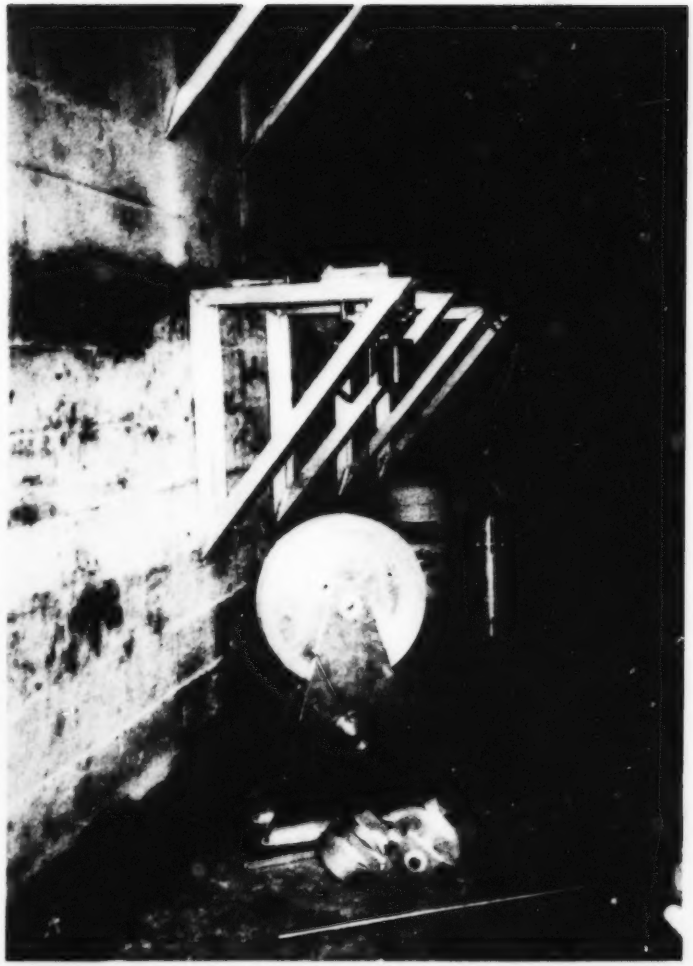


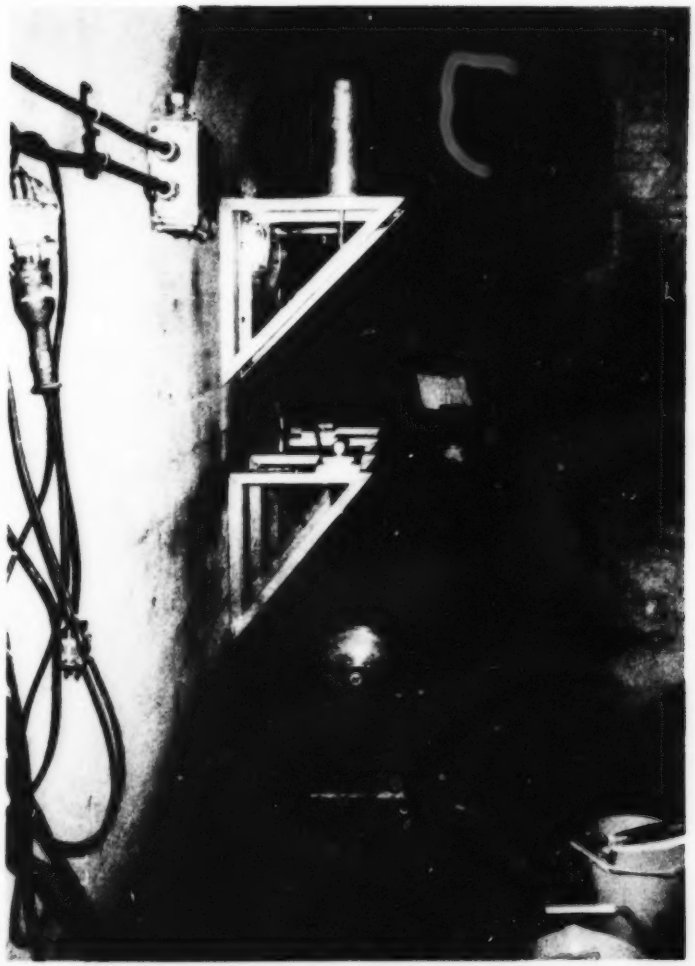
FIGURE 2

PINE PORTAGE GS
INVERSE PENDULUM HOLE

176332-RD
87-328



Foreground: Auto-Centering Device (Probe & ReeL)
Background: Pendulum Reading Tables



Foreground: Inverse Pendulum
Background: Normal Pendulum

FIGURE 3

AUTO-CENTERING READINGS AT PINE PORTAGE GS

176326-RD
Bart 2 Disk

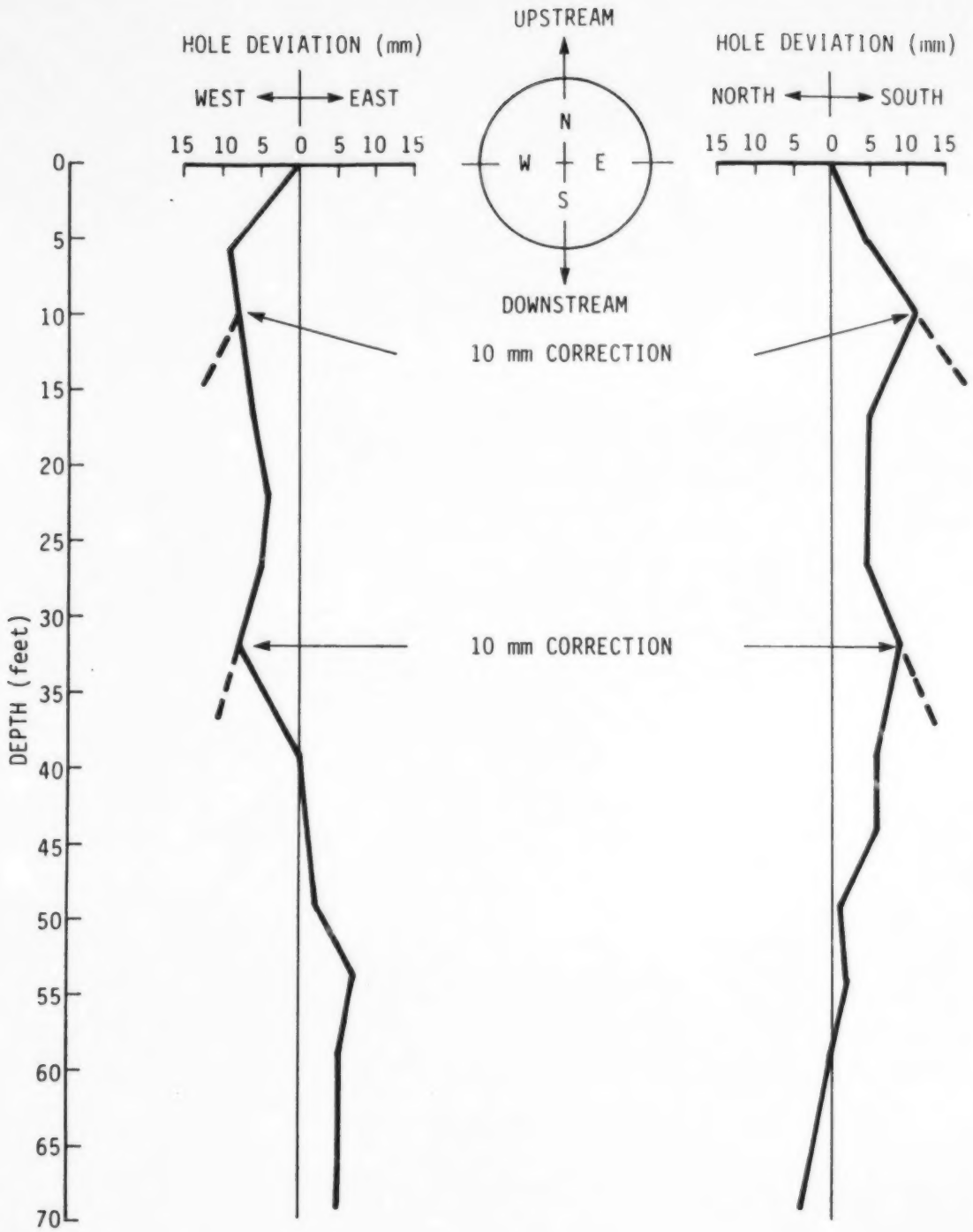
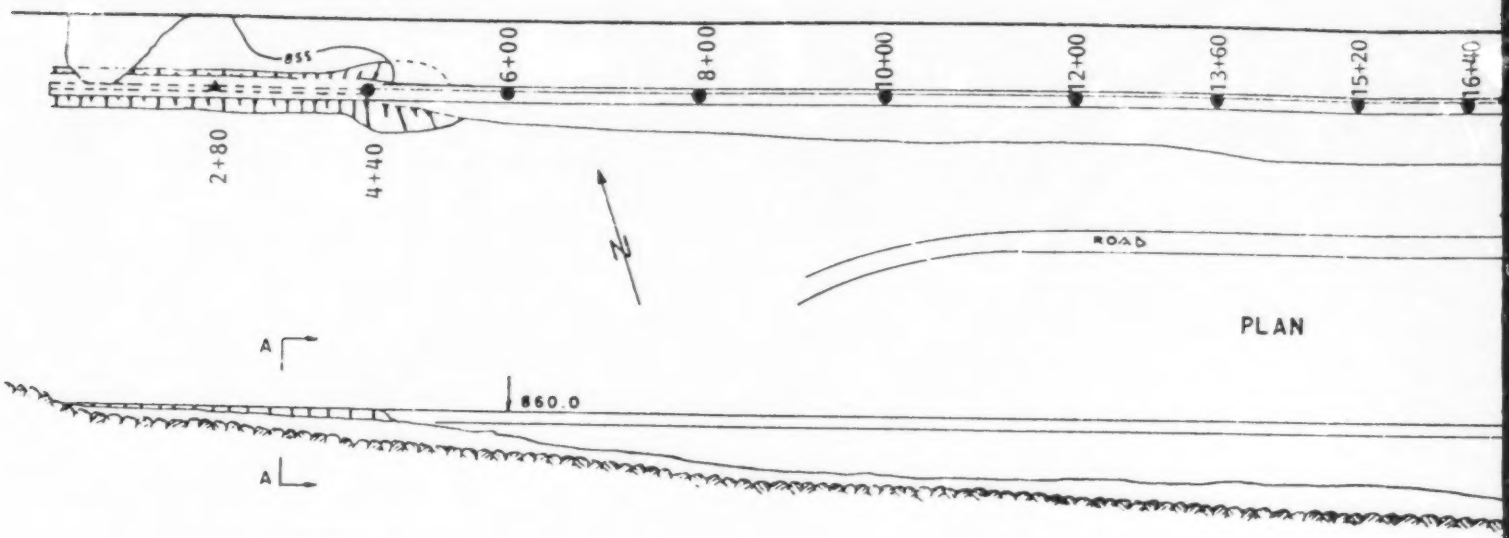


FIGURE 4

PINE PORTAGE GS
NORMAL PENDULUM HOLE



MAIN DAM - POWER HOUSE - SLUICEWA
DOWNSTREAM ELEVATION

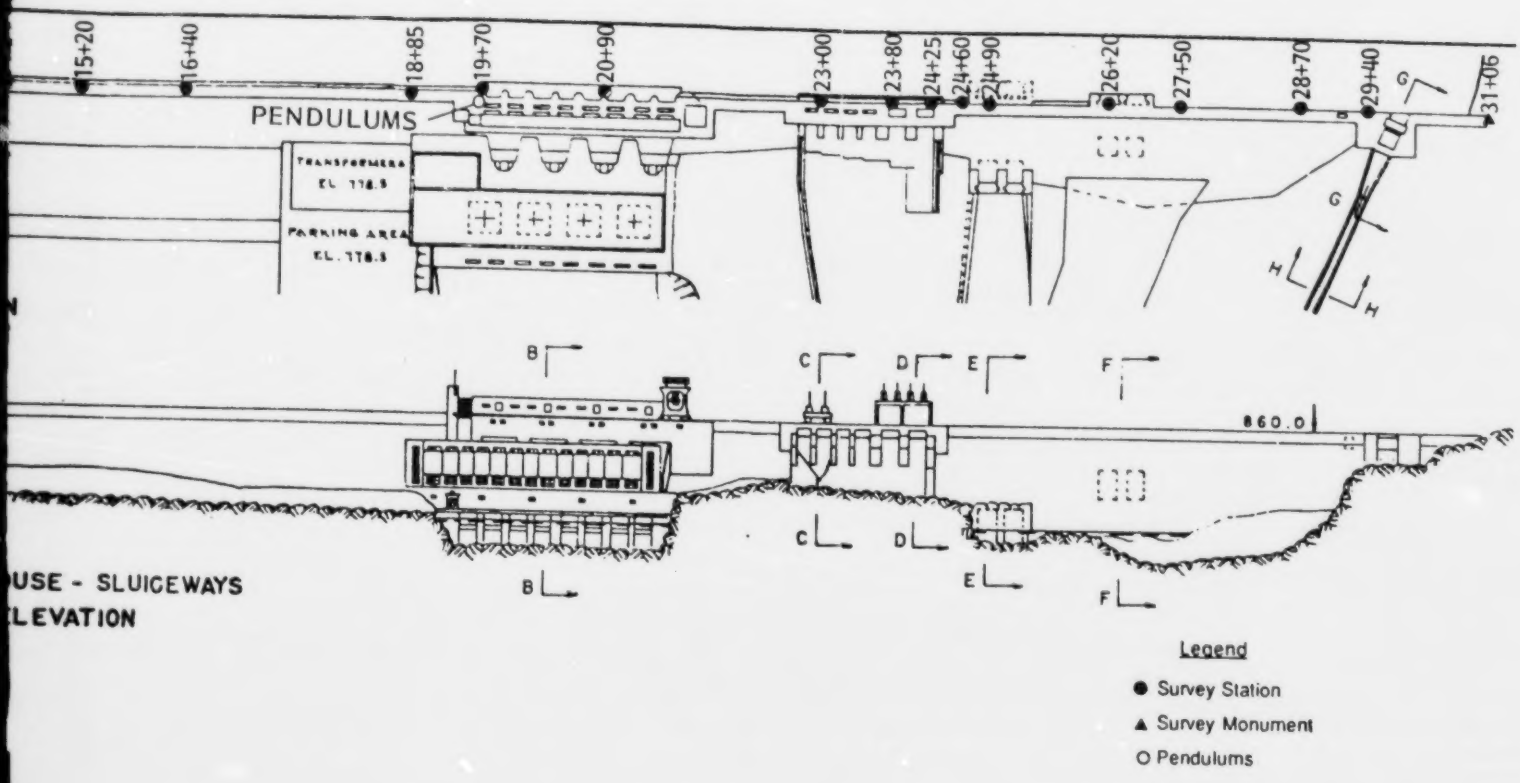


FIGURE 5

PINE PORTAGE GS
INSTRUMENTATION LOCATIONS

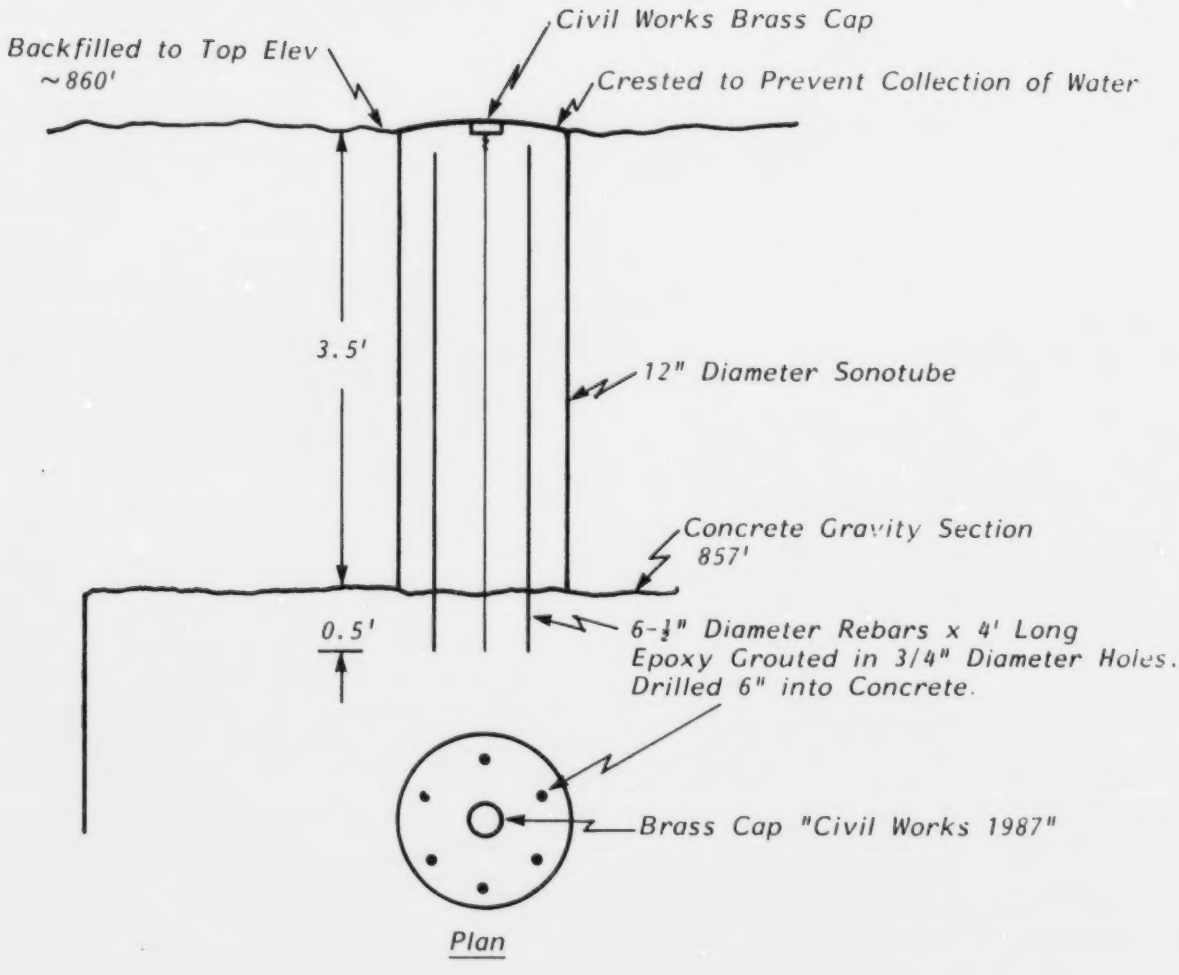


FIGURE 6

PINE PORTAGE GS - WEST MONUMENT (2+80)
CONSTRUCTION DETAILS

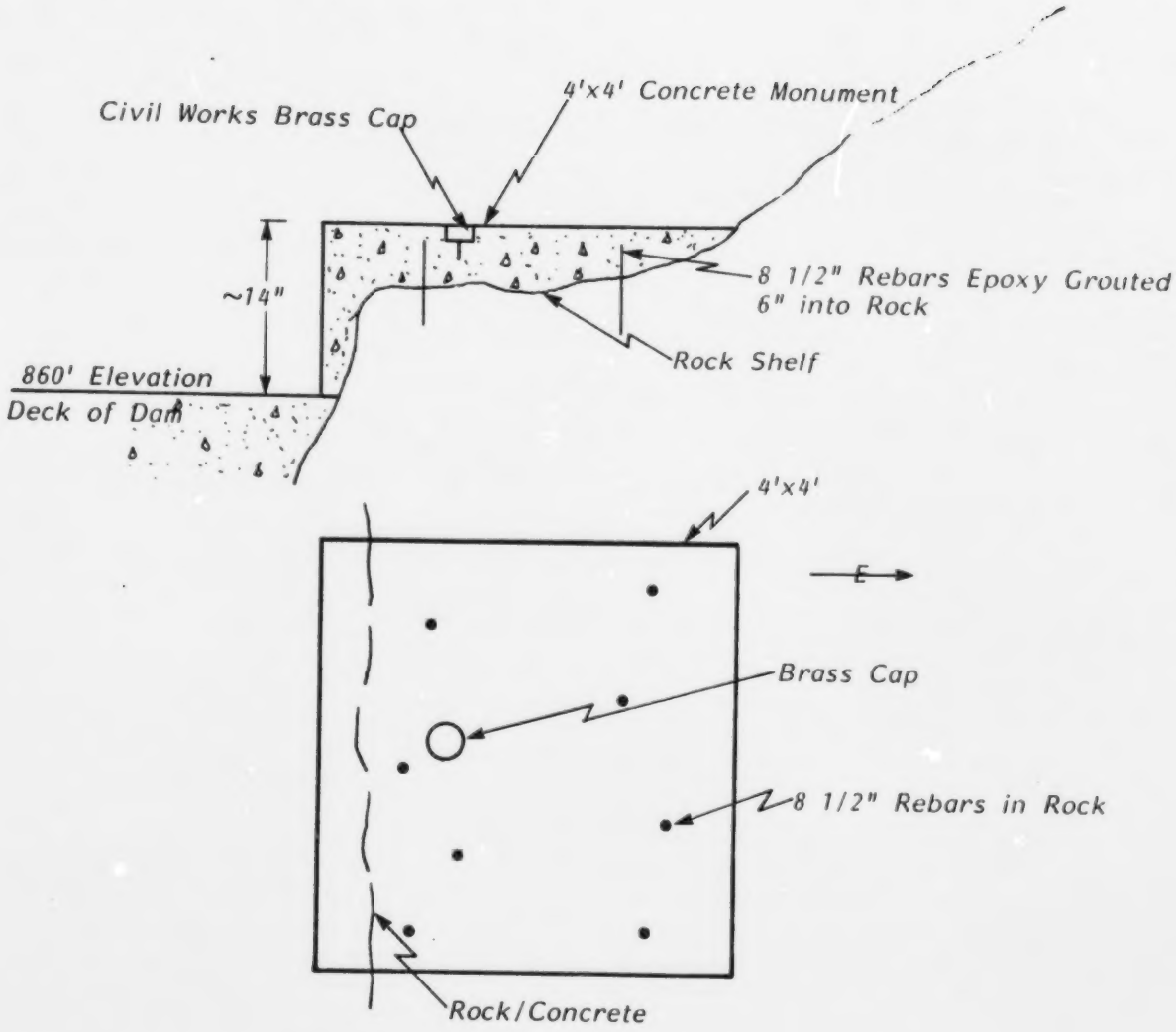


FIGURE 7

PINE PORTAGE GS - EAST MONUMENT (31+06)
CONSTRUCTION DETAILS

West Monument

East Monument

FIGURE 8

PINE PORTAGE GS

176329-RD
Bart 2 Disk

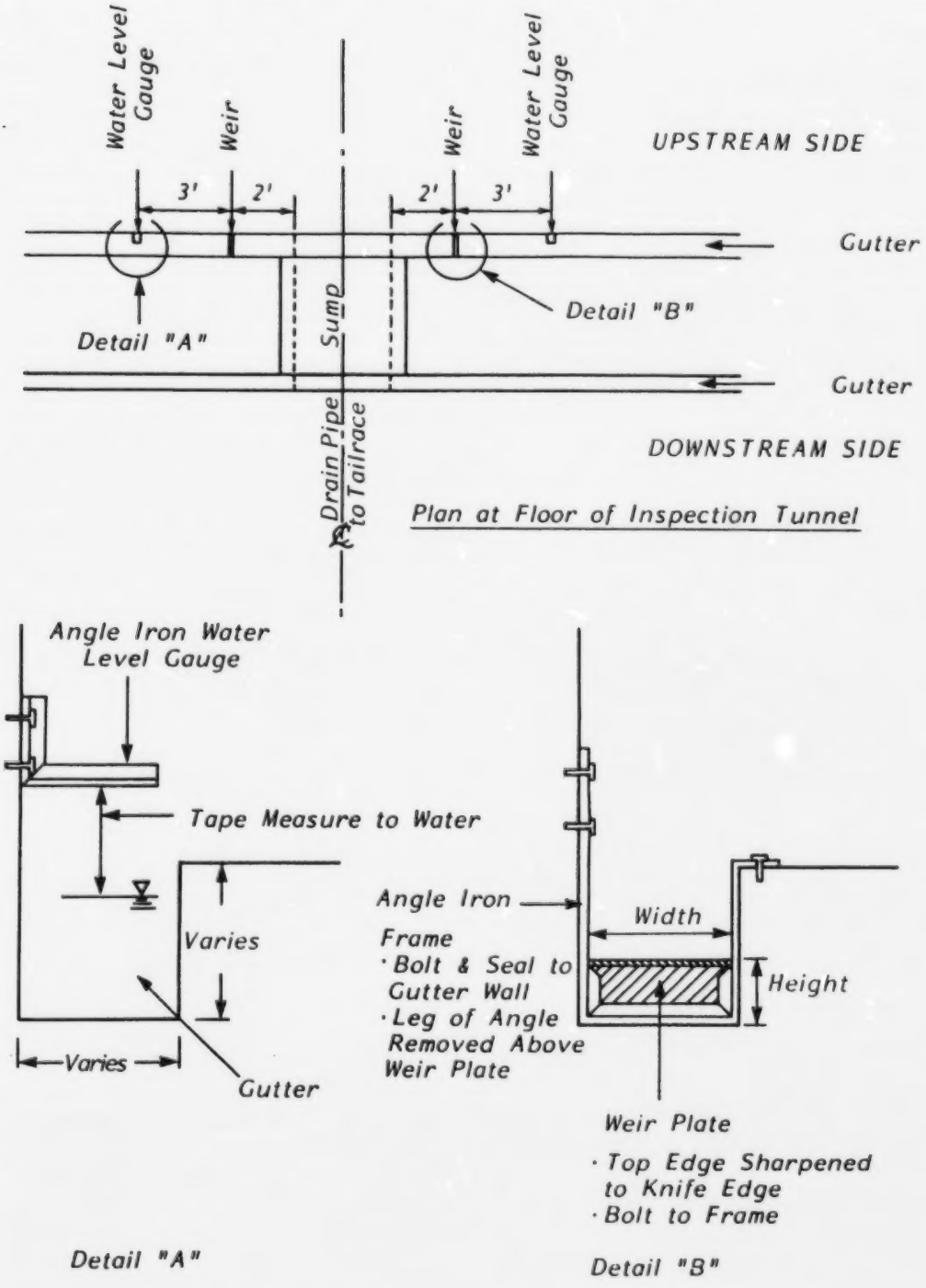


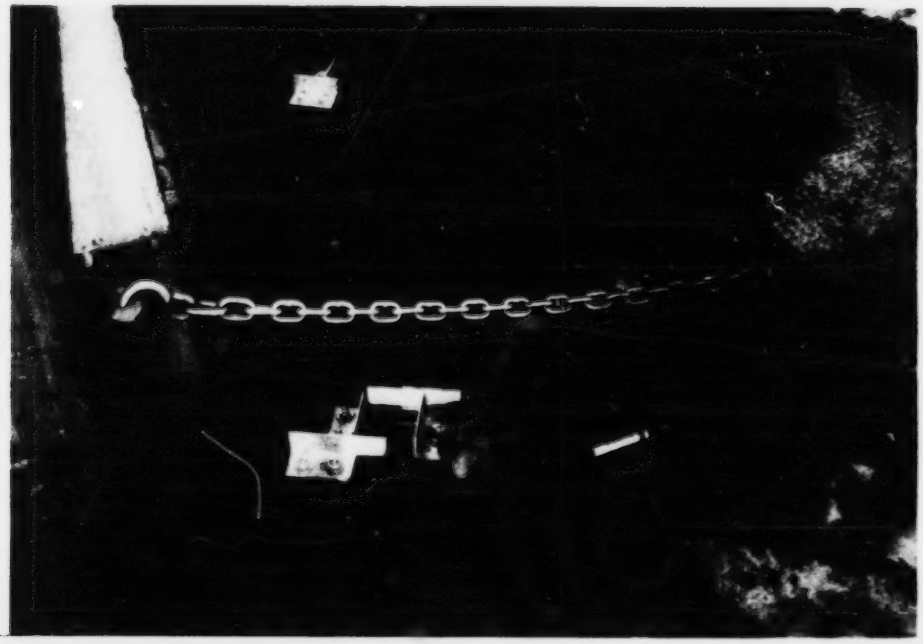
FIGURE 9

PINE PORTAGE GS
INSPECTION TUNNEL WEIRS
GENERAL ARRANGEMENT

176336-RD

87-328

Thermocouple Tree in
Concrete Deck

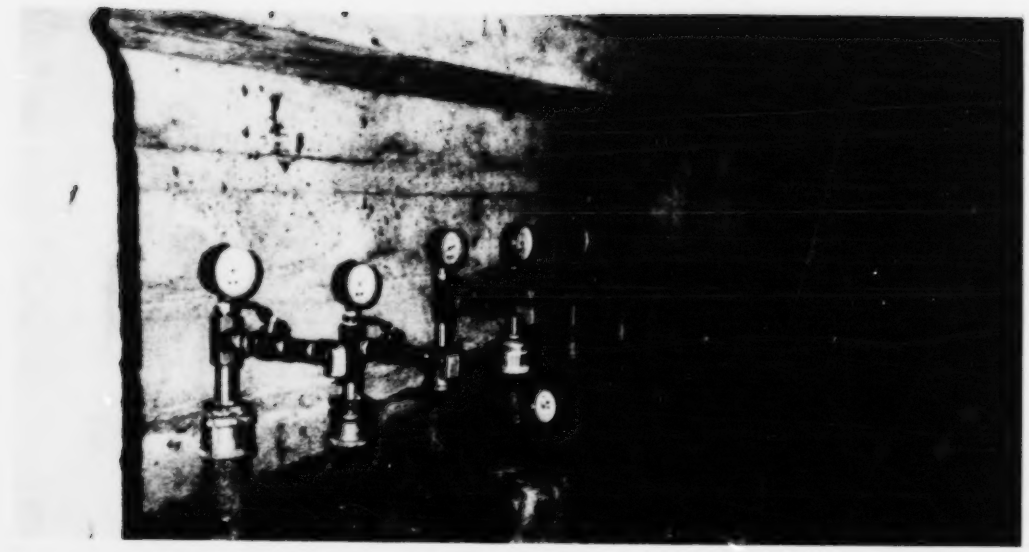


Crack Meter
Monitoring

FIGURE 10

PINE PORTAGE GS

176330-RD
Bart 2 Disk



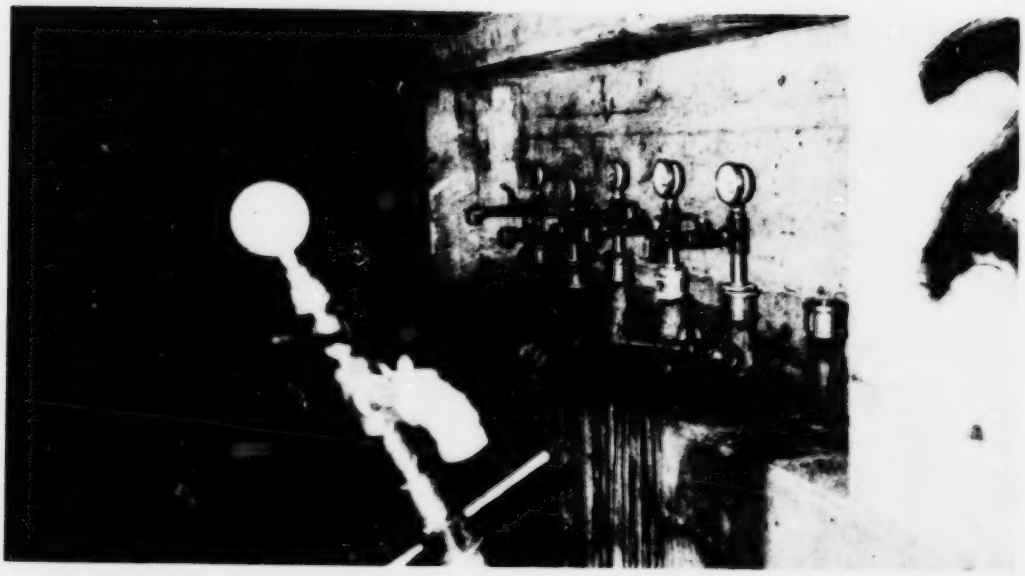


FIGURE 11

PINE PORTAGE GS
REHABILITATED UPLIFT
CELLS AT 28 + 08

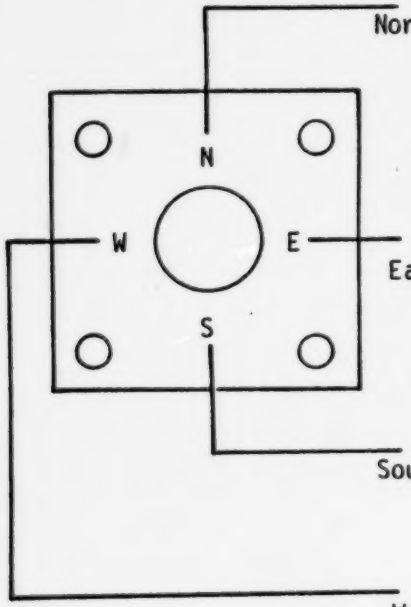
176331-RD
Bart 2 Disk

Forward to: G.F. Smith
Supervisor Dam Safety Unit
A12-H14

PINE PORTAGE GS

Read by: Al Morton

Date: Nov 12, 1987



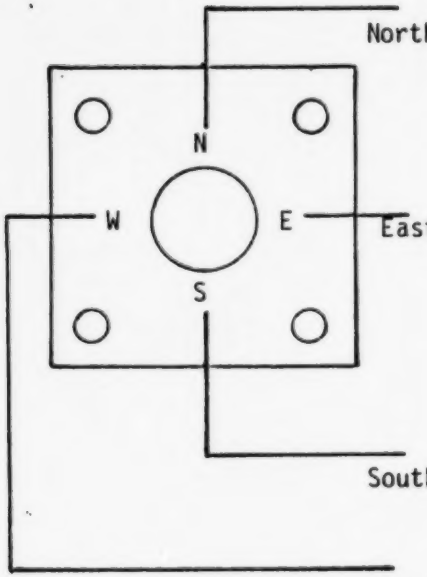
North Reading 1. 1.491
2. 1.489
3. 1.490

East Reading 1. 1.565
2. 1.563
3. 1.562

South Reading 1. 1.589
2. 1.593
3. 1.592

West Reading 1. 1.509
2. 1.511
3. 1.510

*Average (North + South) = 3.082
*Average (East + West) = 3.074
Tiltmeter N-S Facing E 1.24°
E-W Facing S 0.06°



North Reading 1. 1.542
2. 1.542
3. 1.543

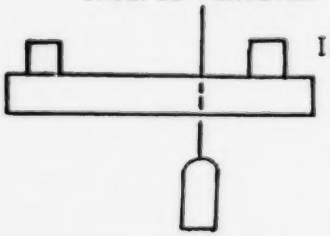
East Reading 1. 1.462
2. 1.462
3. 1.464

South Reading 1. 1.539
2. 1.538
3. 1.538

West Reading 1. 1.626
2. 1.625
3. 1.625

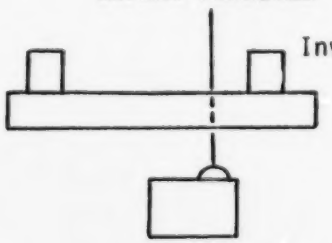
Average (North + South) = 3.080
Average (East + West) = 3.087
Tiltmeter N-S Facing E 0.73°
E-W Facing S 0.85°

Inverse Pendulum



Invar Pin Reading 1. 1.345
2. 1.345
3. 1.346

Normal Pendulum



Invar Block Reading 1. 1.783
2. 1.784
3. 1.783

Note: All readings are to be recorded to the nearest 1/1000th of an inch.
Average North plus South; and East plus West Readings should sum to the totals listed to within 5/1000th of an inch.

TABLE I

TABLE II

PINE PORTAGE GS
SURVEY STATION LOCATIONS

Station	Chainage (ft)
West Monument	2+80
Survey Stations	4+40
	6+00
	8+00
	10+00
	12+00
	13+60
	15+20
	16+40
	18+85
	19+70
	20+90
	23+00
	23+00
	24+25
	24+60
	24+90
	26+20
	27+50
	28+70
	29+40
East Monument	31+06

TABLE III

Weir Construction Details

Location	Approximate Chainage (ft)	Weir Construction Width (ft)	Weir Construction Height (ft)	Weir Construction Type
West Tunnel	14+98	0.83	0.85	V-Notch
	15+02	0.80	0.78	V-Notch
Powerhouse Tunnel	20+13	1.03	1.08	V-Notch
	20+19	1.03	1.08	V-Notch
	21+14	0.99	1.05	V-Notch
	21+20	0.99	1.05	V-Notch
East Tunnel	26+17	0.83	0.50	B-Crested
	26+75	0.84	0.62	B-Crested
	27+38	0.83	0.88	B-Crested
	27+42	0.81	0.88	V-Notch

NOTE: Weir inverts are 0.25' above base of weir except at 26+17 where it is 0.16'

Forward to: G.F. Smith
Supervisor Dam Safety Program
A12-H14

Reading Frequency: Monthly

PINE PORTAGE GS
MAIN DAM INSPECTION TUNNELS

Read by: _____
Date: _____
Headpond Elevation: _____
Tailwater Elevation: _____

WEST INSPECTION TUNNEL

Uplift Cells		Readings psi (1)	Readings feet (2)	Flow (3) (Volume/Time)	Remarks (4)
19+21	1				
	2				
	3				
	4				
	5				
	6				
Weirs		Depth to Water (5)			
15+00	1				
	2				

POWERHOUSE INSPECTION TUNNEL

Weirs		Depth to Water (5)	
Units 1&2	3		
	4		
Units 3&4	5		
	6		

EAST INSPECTION TUNNEL

Uplift Cells		Readings psi (1)	Readings feet (2)	Flow (3) (Volume/Time)	
28+08	1				
	2				
	3				
	4				
	5				
	6				
Observation Wells					
26+25					
28+00					
28+77					
28+79					
29+35					
Weirs		Depth to Water (5)			
26+17	7				
26+73	8				
27+28	9				
27+42	10				

3722h

TABLE IV

87-328

PINE PORTAGE GS
MAIN DAM SLUICEWAY PIERS

Forward to: G.F. Smith
Supervisor Dam Safety Program
A12-H14

Read by: A. Morton. L. O'Neil, R. Nichols
Date: May 13, 1987
Headpond Elevation: 259.51 m
Tailwater Elevation: 227.40 m.

Reading Frequency: Monthly

Crack Meter	Direction of Reading (see Note 2)	Measurement	Remarks
1	East	3.831	
	North	3.736	
2	East	3.872	
	North	3.321	
3	West	3.942	
	North	3.708	
4	East	3.757	
	North	3.755	
5	West	3.049	
	North	3.697	
6	East	3.306	
	South	3.770	
7	East	3.403	
	North	3.845	
8	East	3.660	
	North	3.536	

Thermocouple	Location of Tip	Reading (Degrees) (see Note 3)	Remarks
1	Ambient	44.3 °F	
2	6 inches below deck	40.2 °F	
3	12 inches below deck	40.4 °F	
4	18 inches below deck	39.9 °F	

Notes:

1. Crack meter measurements should be recorded to the nearest 1/1000 inch.
2. The direction the crack meter readings are taken from is only approximate.
3. Thermocouple readings may be measured in either degrees Celsius (°C) or Fahrenheit (°F). Please record the units used.
4. Any comments regarding unusual or changes in conditions noted during monitoring should be recorded in the "Remarks" column. This column should also be used to note any required instrumentation repairs.

TABLE V

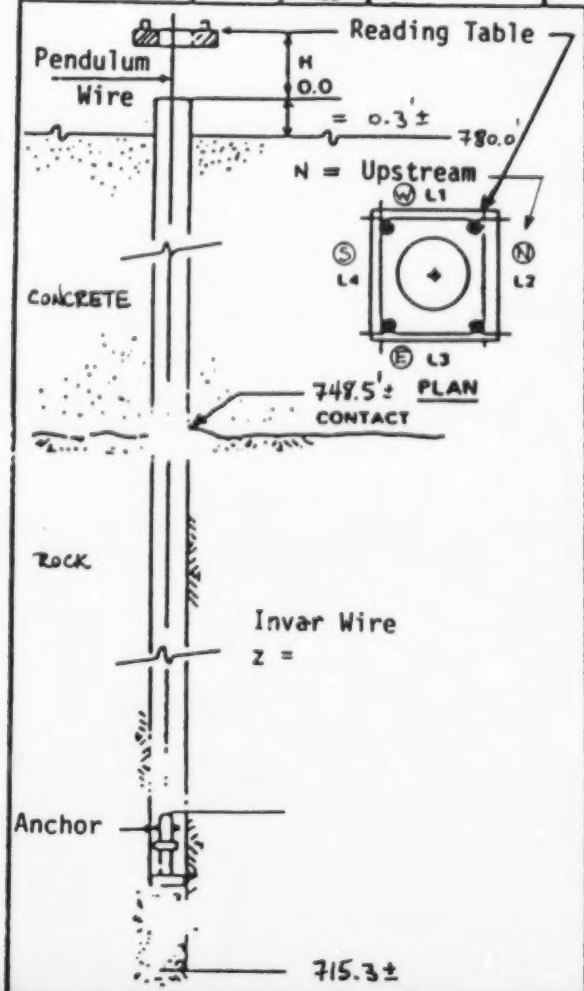
3722h

APPENDIX A

Pine Portage GS
Inverse Pendulum
Initial Autocentering Device Readings

	Inverted Pendulum Datum Readings	Page 1 of 4
DATE: Nov. 12, 1987 TEMP.:		Observer AGM Marker Chainage 19+70 Elevation 780.3±
PROJECT: PINE PORTAGE GS		

Depth (ft)	Axis	Rdg No	Reading Inches	Position	Actual Position	Original Position	Displacement
Reading Table H = 3.2' ±	X	L2	1.490	+0.050	(Px) +0.050		
		L4	1.591				
		L2					
		L4					
	Y	L1	1.510	+0.026	(Py) +0.026		
		L3	1.563				
		L1					
		L3					



Position of centre of the reading table relative to the pendulum anchor

$x = \frac{L4 - L2}{2}$ $y = \frac{L3 - L1}{2}$

Auto centering device
Position of the wire, at various depths relative to the pendulum anchor

$x = \frac{L2 - L4}{2} + Px$

$y = \frac{L1 - L3}{2} + Py$

Table Constant x =

y =

Wire Diameter 0.050"

DATE: NOV. 12, 1987.

TEMP.:

INVERSE PENDULUM
AUTO-CENTERING DEVICE

2 of 4

AGM

PINE PORTAGE GS PLOT:

19+70

780.3 ±

DEPTH (ft)	AXIS		READING (inches)	POSITION	ACTUAL POSITION	ORIGINAL POSITION	DISPLACEMENT
0	X	L2 ↓	1.389	− 0.100	− 0.100		
		L4 ↓	1.689				
		L2 ↑					
		L4 ↑					
	Y	L1 ↓	1.830	+ 0.312	+ 0.312		
		L3 ↓	1.259				
		L1 ↑					
		L3 ↑					
5	X	L2 ↓	1.411	− 0.080	− 0.080		
		L4 ↓	1.670				
		L2 ↑					
		L4 ↑					
	Y	L1 ↓	2.110	+ 0.594	+ 0.594		
		L3 ↓	0.975				
		L1 ↑					
		L3 ↑					
10	X	L2 ↓	1.457	− 0.031	− 0.031		
		L4 ↓	1.618				
		L2 ↑					
		L4 ↑					
	Y	L1 ↓	2.263	+ 0.732	+ 0.732		
		L3 ↓	0.852				
		L1 ↑					
		L3 ↑					
15	X	L2 ↓	1.522	+ 0.031	+ 0.031		
		L4 ↓	1.560				
		L2 ↑					
		L4 ↑					
	Y	L1 ↓	2.233	+ 0.716	+ 0.716		
		L3 ↓	0.854				
		L1 ↑					
		L3 ↑					

Px: + 0.050

(Py + 0.026

DATE: NOV. 12, 1987.

TEMP.:

INVERSE PENDULUM
AUTO-CENTERING DEVICE

3 of 4

AGM

PINE PORTAGE GS PLOT:

19+70

780.3 ±

DEPTH (ft)	AXIS		READING (inches)	POSITION	ACTUAL POSITION	ORIGINAL POSITION	DISPLACEMENT
20	X	L2 ↓	1.494	+0.002	+0.002		
		L4 ↓	1.591				
		L2 ↑					
		L4 ↑					
	Y	L1 ↓	2.140	+0.621	+0.621		
		L3 ↓	0.951				
		L1 ↑					
		L3 ↑					
25	X	L2 ↓	1.420	-0.074	-0.074		
		L4 ↓	1.667				
		L2 ↑					
		L4 ↑					
	Y	L1 ↓	2.084	+0.566	+0.566		
		L3 ↓	1.004				
		L1 ↑					
		L3 ↑					
30	X	L2 ↓	1.393	-0.098	-0.098		
		L4 ↓	1.688				
		L2 ↑					
		L4 ↑					
	Y	L1 ↓	2.088	+0.573	+0.573		
		L3 ↓	0.994				
		L1 ↑					
		L3 ↑					
35	X	L2 ↓	1.424	-0.071	-0.071		
		L4 ↓	1.666				
		L2 ↑					
		L4 ↑					
	Y	L1 ↓	2.114	+0.831	+0.831		
		L3 ↓	0.972				
		L1 ↑					
		L3 ↑					

Px: +0.050

(Py: +0.026

DATE: NOV. 12, 1987.

TEMP.:

INVERSE PENDULUM
AUTO-CENTERING DEVICE

4 of 4

AGM

PINE PORTAGE GS PLOT:

19+70

780.3 ±

DEPTH (ft)	AXIS		READING (inches)	POSITION	ACTUAL POSITION	ORIGINAL POSITION	DISPLACEMENT
40	X	↓ L2	1.482	-0.013	-0.013		
		↓ L4	1.608				
		↑ L2					
		↑ L4					
	Y	↓ L1	2.137	+0.852	+0.852		
		↓ L3	0.953				
		↑ L1					
		↑ L3					
45	X	↓ L2	1.484	-0.012	-0.012		
		↓ L4	1.608				
		↑ L2					
		↑ L4					
	Y	↓ L1	2.090	+0.573	+0.573		
		↓ L3	0.996				
		↑ L1					
		↑ L3					
50	X	↓ L2	1.532	+0.034	+0.034		
		↓ L4	1.565				
		↑ L2					
		↑ L4					
	Y	↓ L1	2.011	+0.488	+0.488		
		↓ L3	1.088				
		↑ L1					
		↑ L3					
55	X	↓ L2	1.545	+0.044	+0.044		
		↓ L4	1.557				
		↑ L2					
		↑ L4					
	Y	↓ L1	1.893	+0.376	+0.376		
		↓ L3	1.193				
		↑ L1					
		↑ L3					

Pw: +0.050

(Py: +0.026

APPENDIX B

Pine Portage GS
Initial Survey Measurements
(by Civil Works Personnel)

Station Chainage nominal (ft)	Station Chainage actual (ft)	Elevation (inches)	Offset From Sight Line[1] (mm)
2+80	2+80.46	10,320.313	reference point
4+40	4+40.32	10,312.652	- 8.0
6+00	6+00.34	10,312.847	-50.8
8+00	8+00.30	10,312.997	- 4.9
10+00	10+00.32	10,313.071	- 2.8
12+00	12+00.27	10,313.025	- 1.4
13+60	13+60.29	10,313.056	- 2.2
15+20	15+20.26	10,312.521	- 3.2
16+40	16+40.24	10,312.619	- 3.2
18+85	18+85.29	10,312.913	- 1.0
19+70	19+70.27	10,312.498	reference point
20+90	*	*	*
23+00	*	*	*
23+80	*	*	*
24+25	24+25.27	10,312.939	0.9
24+60	24+60.36	10,313.478	- 0.6
24+90	24+90.30	10,313.658	0.6
26+20	26+20.26	10,313.318	5.9
27+50	27+50.31	10,313.189	0.5
28+70	28+70.33	10,313.001	16.4
29+40	29+40.25	10,312.935	0.4
31+06	31+06.31	10,340.626	reference point

NOTES:

*not installed at time of survey (Oct 4/87)

1 $+_{ve}$ offsets are upstream of reference line;

$-_{ve}$ offsets are downstream of reference line